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LEVEL II

# EVALUATION OF THE E-FIELD SENSOR, MODEL EFS-1 (INSTRUMENTS FOR INDUSTRY, INC.)



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## NOTICES

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This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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The response of two Model EFS-1 field-strength meters (~~Instruments for Industry, Inc.~~) was measured when exposed to 10, 20, 30, 40, and 50 MHz fields. This electric field sensor is advertised as responding directly from 10 kHz to 200 MHz. Tests were completed for continuous wave and pulsed square wave exposure conditions. These test results indicate that the EFS-1 would be a useful radiofrequency radiation field sensor.

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# CONTENTS



## Figure



## Tables

# EVALUATION OF THE E-FIELD SENSOR, MODEL EFS-1
# (INSTRUMENTS FOR INDUSTRY, INC.)

## INTRODUCTION

Convenient and inexpensive devices for measuring radiofrequency radiation (RFR) fields are needed, both by researchers studying RFR field effects and by safety personnel interested in the RFR levels which workers and the public encounter. Presently available are several instruments, with various degrees of sophistication, which could be useful for this purpose. This report describes the response of one such potentially useful device to continuous wave (CW) and pulsed square wave RFR in the frequency range of 10 - 50 MHz.

## MATERIALS

### Devices Tested

The units evaluated were Instruments for Industry, Inc. (IFI) Model EFS-1 field-strength meters (Serial Nos. 523 and 524). These units were equipped with a Model LMT-B (Serial No. 259) light modulator transmitter and a Model LDI (Serial No. 125) light demodulator indicator with manufacturer specifications of direct reading from 10 kHz to 200 MHz. The EFS-1 meters were calibrated at the factory on 27 July 1977; the LMT-B and LDI, on 27 September 1977.

The IFI field-strength meter is battery-operated and housed in a metal container measuring 10 x 10 x 4.5 cm (4 x 4 x 1.75 in.). Three antennas are supplied for measuring five different field intensity ranges. The 10 cm antenna is used when the field to be measured is between 1 and 10 volts per meter (V/m). The 2.5 cm antenna is used when the field is more than 10 V/m, but less than 100 V/m; and the 1 cm antenna is used for fields from 100 to 300 V/m.

A range switch is located on the front panel of the EFS-1 for selecting the sensitivity of the meter. When the longest antenna is used and the switch is in the HI range position, the meter is calibrated for 3 - 10 V/m. In the LO range position, the meter is calibrated for 1 - 3 V/m. Similarly, when the 2.5 cm antenna is used, a meter range of either 30 - 100 V/m or 10 - 30 V/m is available. With the 1 cm antenna, the meter is calibrated to read fields from 100 to 300 V/m (Table 1).

EDITOR'S NOTE: Available on p. 9 is a selective list, plus definitions, of the "Abbreviations" used throughout this report.

The address of Instruments for Industry, Inc., is: 151 Toledo St., Farmingdale, N.Y. 11735.

TABLE 1. RANGE OF SENSITIVITY OF THE EFS-1 FIELD-STRENGTH METER

| Antenna Length (cm) | Antenna Range V/m | EFS-1 Meter | |
|---|---|---|---|
| 10 | 1-10 | HI | 3-10 |
| | | LO | 1-3 |
| 2.5 | 10-100 | HI | 30-100 |
| | | LO | 10-30 |
| 1 | 100-300 | HI | 100-300 |

The light modulator transmitter and light demodulator indicator (LMT/LDI) combination is a remote reading system which permits reading of the EFS-1 over a light pipe which can range up to approximately 8 m in length.

As a check on the reliability of the EFS-1, a procedure for recalibrating the instruments is furnished as part of the operation manual.

### Test Apparatus

The tests were made in a high-frequency (HF) band "far-field" exposure device (TEM Mode Chamber) which was 9.15 m long, 2.82 m wide, and 1.45 m high, with a thin aluminum center conductor, 1.89 m wide. The driver stage of the Microwave Cavity Laboratories (MCL) Model 15022 was used to supply 10, 20, 30, 40, and 50 MHz RFR. Electric (E) field readings were taken with a portable E-field probe and a Kiethly Model 600-B electrometer.

The input power was monitored through a National Bureau of Standards (NBS) Model DCI/350C, 40 dB coupler with a Hewlett Packard (HP) Model 432B power meter and HP Model 478A (H-55 option) thermistor mount. For the pulsed portion of the test, a Tektronix Type 321 oscilloscope was used to monitor the pulse width; and a Beckman Model 7160 frequency counter was used to measure the pulse repetition rate (prr) from the MCL pulse generator (Fig. 1).

## METHODS AND PROCEDURES

The warm-up and initial instruments' zeroing procedures, outlined in the EFS-1 operator instruction manual, were followed before each series of tests.

The E-field was measured at the test location with an NBS-constructed and -calibrated 10-cm dipole, connected via high resistive leads to an electrometer. The relation between the input power and the E-field for each frequency was established for the maximum input power available with

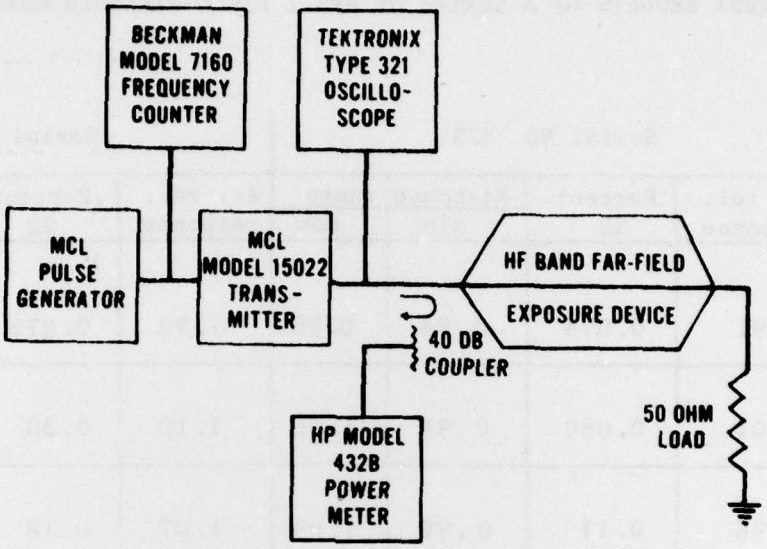


Figure 1. Exposure setup to evaluate the Model EFS-1 field-strength meters, Serial Nos. 523 and 524.

the MCL. All other E-field values during the test were determined by using the relation that E-field was proportional to the square root of the input power.

The devices tested were placed in the center of the TEM mode chamber on 10 cm of styrofoam. Both EFS-1 units were tested with the LMT/LDI combination for 10, 20, 30, 40, and 50 MHz in CW fields between 1 and approximately 80 V/m. The EFS-1 units were also tested without the LMT/LDI combination for 10 and 50 MHz CW fields.

For the pulsed square wave fields at 10 and 50 MHz, the EFS-1/LMT/LDI combination was tested for duty factors down to about 0.1, with prr's of 50K, 10K, 1K, and 100 pulses per second (pps).

## RESULTS

### CW Tests

Each CW test comprised a series of approximately twenty readings taken over a range from 1 to about 80 V/m. The results of these CW tests are listed in the top seven rows of Table 2. The first column contains the average of the EFS-1 (Serial No. 523) readings normalized to the E-fields, as measured with the NBS dipole. The percent standard

TABLE 2. TEST RESULTS OF A SERIES OF EFS-1 FIELD-STRENGTH METER READINGS

| | Serial No. 523 | | | | Serial No. 524 | | | |
|---|---|---|---|---|---|---|---|---|
| | Av. rel. response | Percent SD | Response range min | Response range max | Av. rel. response | Percent SD | Response range min | Response range max |
| EFS/LMT 10 MHz (CW) | 0.91 | 0.074 | 0.84 | 0.96 | 0.99 | 0.076 | 0.92 | 1.01 |
| EFS/LMT 20 MHz (CW) | 1.01 | 0.089 | 0.94 | 1.06 | 1.10 | 0.20 | 1.00 | 1.22 |
| EFS/LMT 30 MHz (CW) | 0.98 | 0.11 | 0.90 | 1.04 | 1.07 | 0.18 | 0.95 | 1.11 |
| EFS/LMT 40 MHz (CW) | 0.99 | 0.075 | 0.94 | 1.04 | 1.08 | 0.034 | 1.05 | 1.11 |
| EFS/LMT 50 MHz (CW) | 0.94 | 0.084 | 0.88 | 0.99 | 1.01 | 0.11 | 0.92 | 1.05 |
| EFS-1 10 MHz (CW) | 0.93 | 0.013 | 0.82 | 0.97 | 1.03 | 0.057 | 0.98 | 1.06 |
| EFS-1 50 MHz (CW) | 0.95 | 0.040 | 0.92 | 0.98 | 1.06 | 0.14 | 0.98 | 1.13 |
| EFS/LMT 10 MHz (pulsed) | 0.91 | 0.24 | 0.82 | 1.09 | 1.01 | 0.034 | 0.98 | 1.05 |
| EFS/LMT 50 MHz (pulsed) | 0.90 | 0.010 | 0.88 | 0.94 | 1.02 | 0,054 | 0.99 | 1.13 |

deviation for the tests is in the second column. The range of the readings is indicated by the minimum and maximum normalized readings, in columns three and four, respectively. Columns five through eight contain similar data for Serial No. 524.

The largest deviation in the responses, as indicated by the minimum and maximum readings, generally occurred when the lower portion of the scale was used. Readings cannot be made as accurately in this area of the scale. Due to the limited scale selectability, there is no scale overlap; and therefore no options exist to read on a different part of the scale.

These data, for both the EFS-1 and EFS-1 LMT/LDI tests, indicate that the Serial No. 524 reading is, on the average, about 10% higher than that of Serial No. 523. The units also have approximately a 6% lower response at 10 and 50 MHz than at 20, 30, and 40 MHz. However, both devices functioned quite satisfactorily over the frequency range tested.

## Pulsed Square Wave Tests

The EFS-1 devices did not respond properly to the E-field levels for the pulsed square wave tests. The units did respond, however, to what might be called the "average E-field," which is defined as the E-field that would result from a CW field with an equivalent input power--that is, fields having equal average power density values. The prr values used for the pulsed square wave tests were 50K, 10K, 1K, and 100 pps, with the duty factor ranging from 1 to 0.1, in steps of about 0.1 for each prr. The E-field was approximately 30 V/m. The results of the pulsed tests relative to the average E-field (constituting the two bottom rows of Table 2) agree with the CW findings.

## CONCLUSIONS

The Instruments for Industry EFS-1 units that were tested functioned satisfactorily over the frequency range of 10-50 MHz in CW fields less than 100 V/m. As with any RFR measuring device, however, precautions should be taken to assure that standing waves are minimized by eliminating reflective surfaces in proximity to the meter. The use of remote monitoring devices, such as the LMT/LDI combination, can eliminate field perturbations resulting from personnel standing near the meter. The remote reading unit would also allow personnel to measure potentially hazardous levels of RFR while remaining in areas that are safe.

For pulsed square wave RFR fields, one should be careful not to misinterpret the EFS-1 readings. The meter actually indicates the average E-field instead of the actual E-field. If the RFR is a far-field radiation signal, then the power density can be derived by applying the EFS-1 reading to the following well-known expression:

$$\text{P.D. } (\text{mW/cm}^2) = E^2/3770,$$

in which E is the meter reading in volts per meter.

In modulated RFR fields, the peculiarities of the IFI Model EFS-1 field-strength meter response must be kept in mind in order to avoid erroneous interpretations of the readings. However, the meter can be used to measure CW RFR E-fields directly, with reasonable accuracy, in the frequency range of 10 - 50 MHz.

## ABBREVIATIONS

| | |
|---|---|
| CW | continuous wave |
| E-field | electric field |
| EFS-1 | field strength meter for measuring RFR |
| HF | high frequency |
| HP | Hewlett Packard |
| IFI | Instruments for Industry, Inc. |
| K | thousand(s) |
| kHz | kilohertz |
| LDI | light demodulator indicator |
| LMT | light modulator transmitter |
| m | meter(s) |
| MCL | Microwave Cavity Laboratories |
| MHz | megahertz |
| P.D. | power density |
| prr | pulse repetition rate |
| RFR | radiofrequency radiation |
| SD | standard deviation |
| TEM | transverse electromagnetic |
| V/m | volt(s) per meter |